Ecosystems ◆ Climate ◆ Energy and Minerals ◆ Natural Hazards ◆ Environment and Human Health ◆ Water

Scenarios and LULC Modeling for the LandCarbon Project and Beyond – A “producer’s” perspective on land cover drivers

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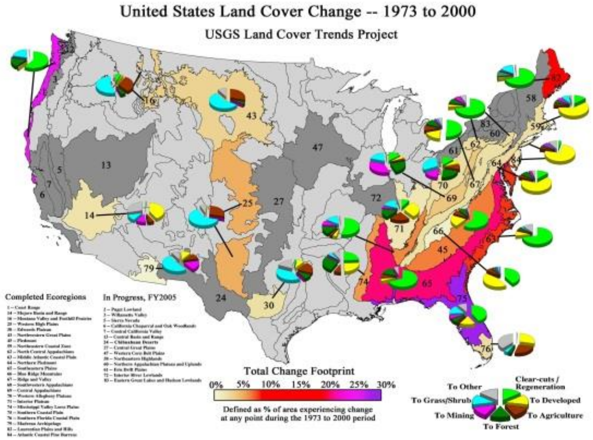
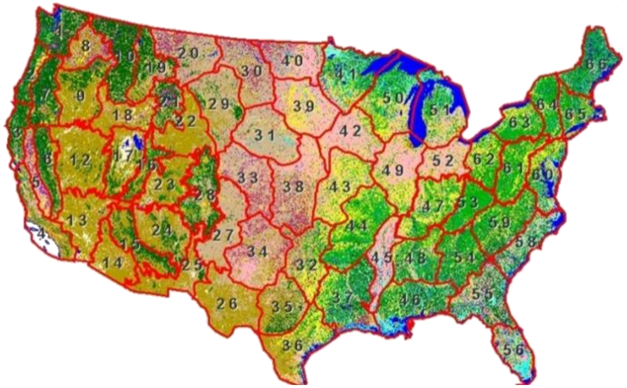
Land-cover Modeling at USGS EROS - History

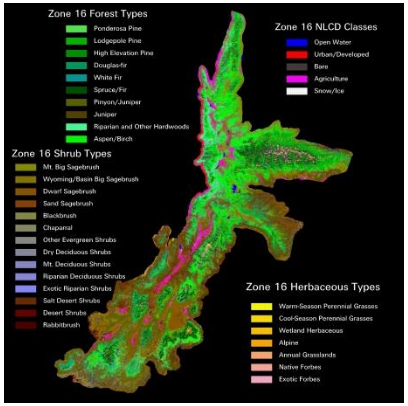
- **Land-use and land-cover (LULC) modeling at EROS began ~2004**
  - Time when several national-scale land cover mapping efforts were underway
  - NASA ROSES proposal for impact of LULC change on weather/climate (Loveland, Pielke Sr., Sohl, Steyaert)

Land Cover Trends





National Land Cover Database (NLCD)



LandFire

Basic Structure – USGS EROS "FORE-SCE" Model

FOREcasting SCEnarios of land-cover (FORE-SCE) model: A modular approach to drivers and issues of scale:

- **Non-spatial "Demand" module provides overall proportions of LULC change for future dates *(Answers "How Much?")***
  - **Largely dependent on "top-down" drivers of LULC change, including those that are non-spatial**
  - **Very flexible in methodology to produce demand**
    - **We've used extrapolations of historical data, economic models, targeted scenario construction, integrated assessment models**
    - **Can use either regional proportions of LULC, or complete transition matrix**
- **"Spatial allocation" component ingests "demand" and produces spatially explicit LULC maps *(Answers "Where?")***
  - **Largely dependent on "bottom-up" drivers of LULC change**
  - **Requires spatially explicit supporting data**
  - **Flexibility to operate at multiple spatial and thematic resolutions**

USGS LandCarbon Assessment

Research Questions:

- What is biological carbon sequestration capacity and greenhouse gas fluxes under multiple future scenarios?
- How effective are management practices on short- and long-term carbon sequestration and GHG flux mitigation?
- How effective are changes in land use on carbon sequestration and GHG flux mitigation?
- What might be the most effective and/or feasible mitigation strategies?
- How might mitigation strategies impact other ecosystem services?

Scope:

- Five primary ecosystems: forests, shrub/grasslands, croplands, wetlands and aquatic (rivers, lakes, coastal waters) systems
- Two types of assessment: baseline ("present-day") and future projection (to 2050)
- Carbon storage and sequestration; fluxes of CO_2, N_2O, and CH_4
- Effects of natural and anthropogenic processes (e.g. climate change, wildfire, land use change, and land management activities)

“Demand” and Scenario Construction

Regional Scenarios Consistent with SRES

Components of Scenario Construction

Population, economic growth, technologic innovation environmental awareness, governance, regulatory regime, biophysical conditions, natural resource base

LULC Histories (LC Trends)

- Recent historical estimates of gross and net LULC change
- Gains, losses
- Conversions
- Ecoregion-based
- Summary reports and driving forces

IAM’s (IMAGE 2.2)

- Integrated drivers (climate, demographics, economics, etc.)
- National and gridded agriculture and forestry
- National land management (biofuels, fertilizer use, energy demand, etc…)

Expert Judgment

- Global scenarios (SRES, RPA, MA, CCSP, RCPs)
- External modeling (ICLUS, RPA, FASOM-GHG)
- National inventories (NLCD, CENSUS, AGCENSUS, FIA, NRI, PAD)
- Downscaling Literature (Gridded, EURURALIS, ATEAM)

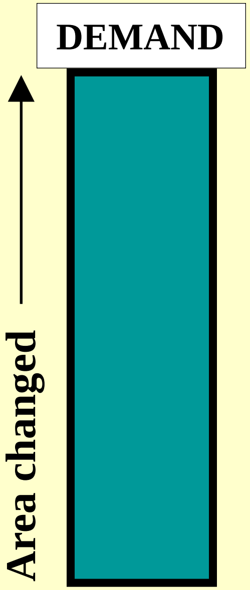
FORE-SCE: Patch-based Spatial Allocation

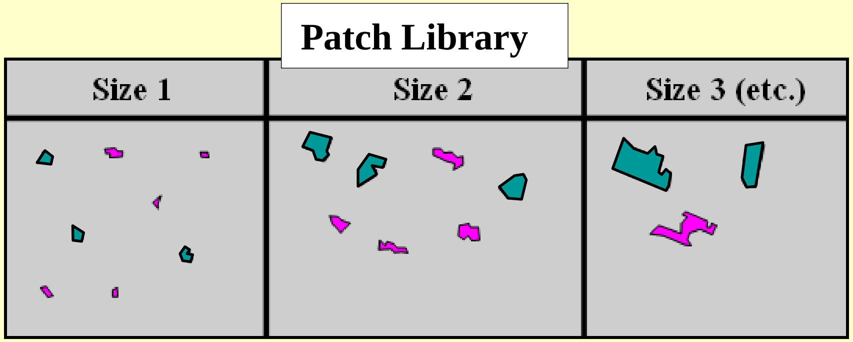
FORE-SCE uses a unique, patch-based spatial allocation procedure

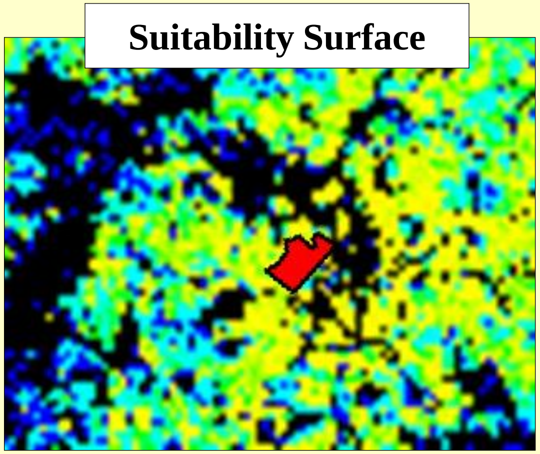
- **An individual patch of a new LULC class is placed on the landscape, and the area of LULC change is tabulated.**
  - **Patch characteristics defined by historical, regional data**
- **FORE-SCE loops back and repeats the process, with patches continually placed on the landscape, until DEMAND for LULC(x) is met**
- **Once DEMAND for LULC(x) is met, the process continues with LULC(x+1), until all land cover types have been modeled**

Two user-selected options in FORE-SCE for patch placement:

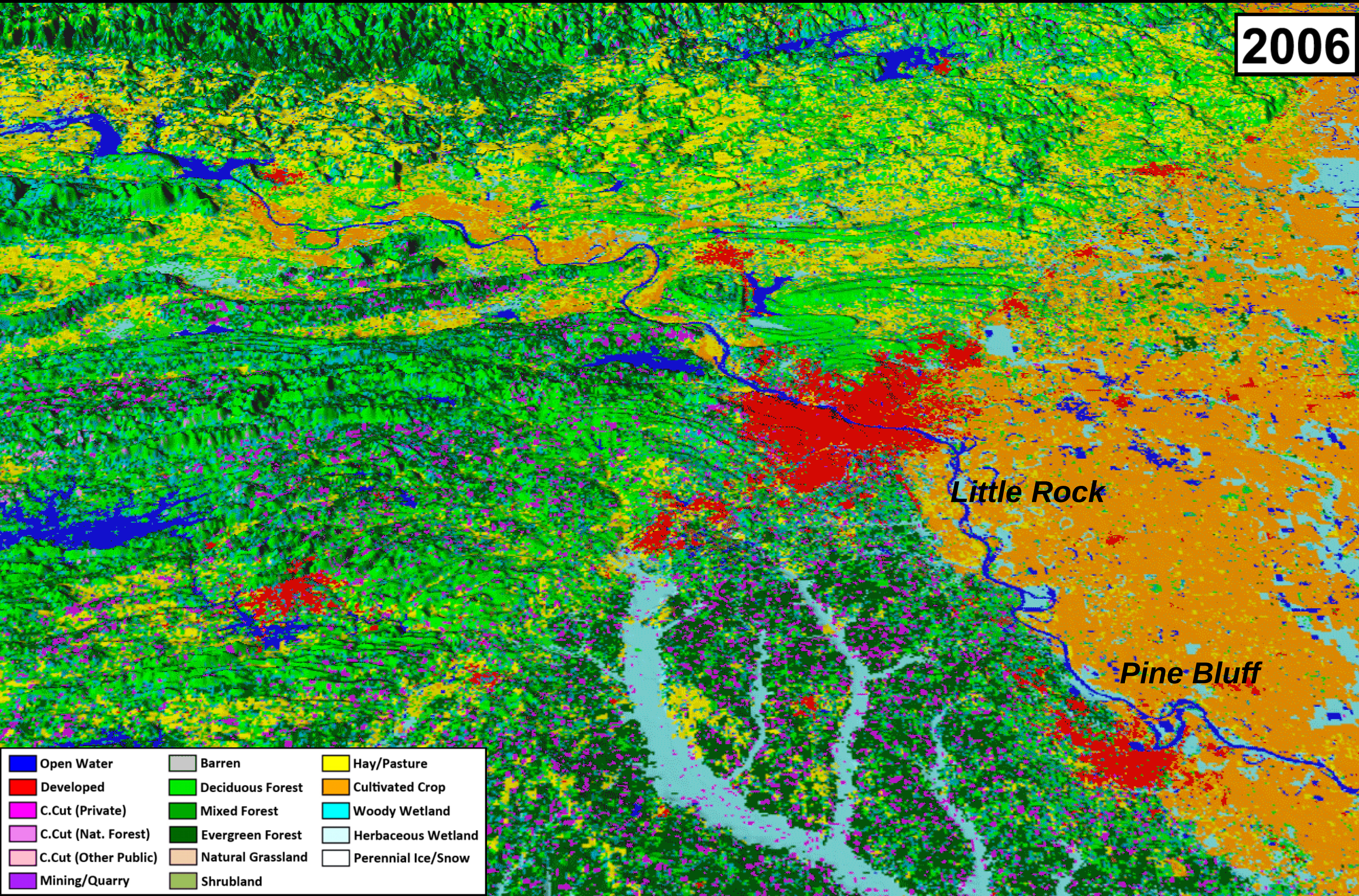
1. **Patch grow algorithm (patches "grow" from seed pixel) (*slower*)**
2. **Patch library (below) (*faster*)**



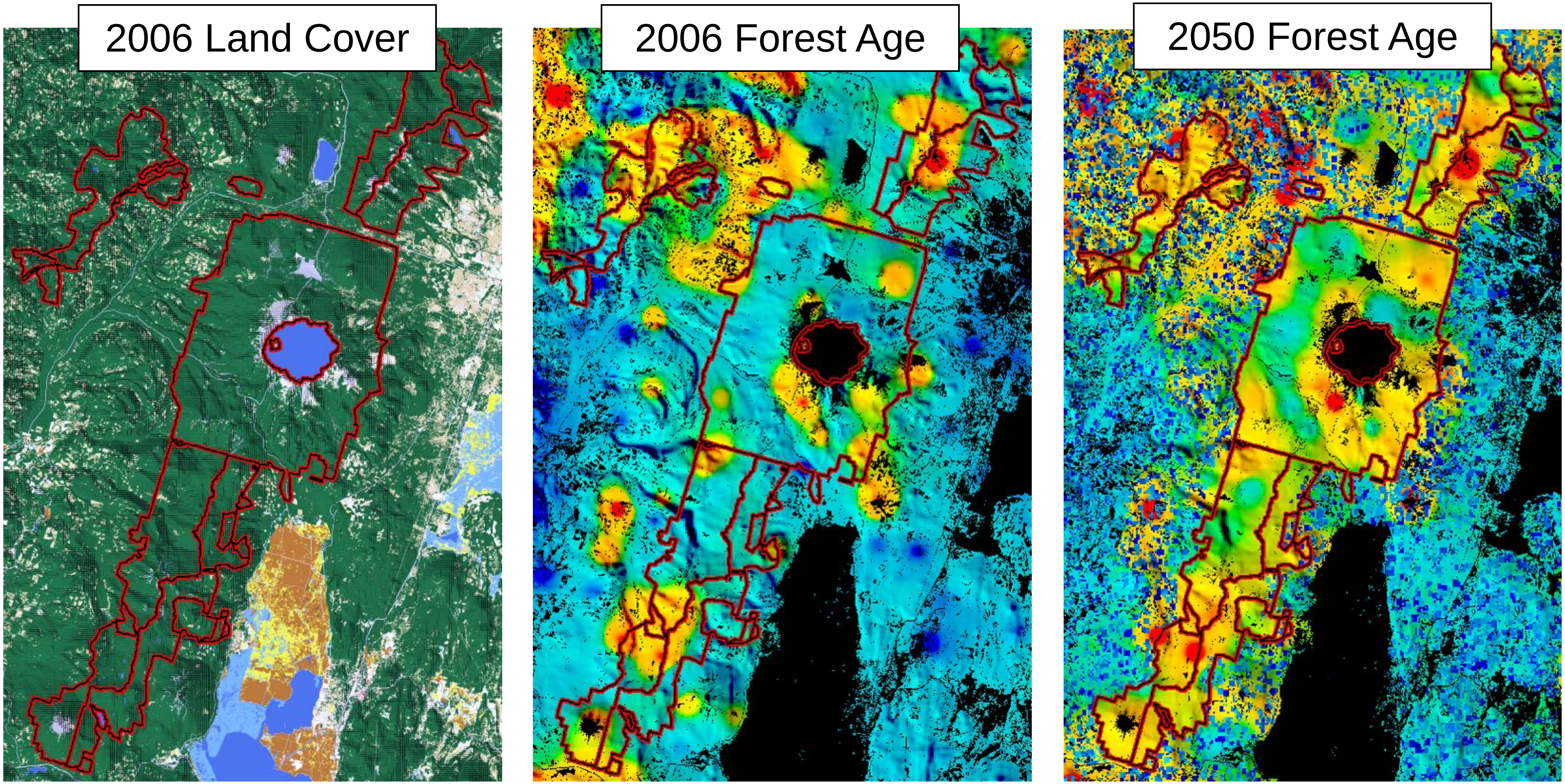




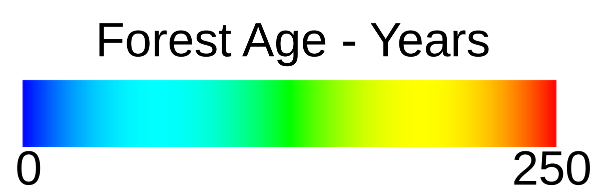
Completed – Four IPCC SRES Projections for conterminous U.S. 1992 to 2100, 250-meter resolution, 16 LULC classes



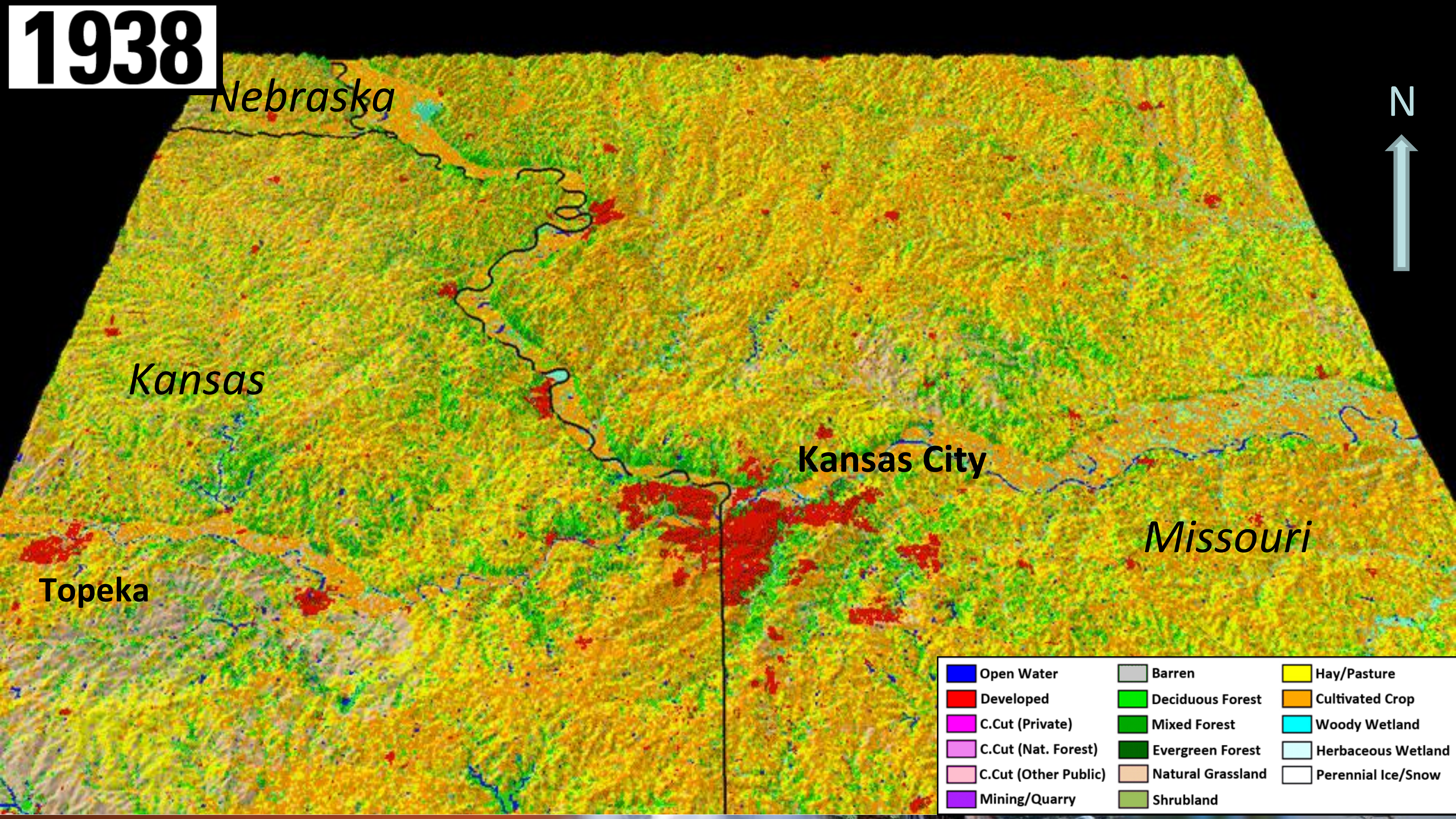
FORE-SCE – Stand Age and Protected Lands



Open Water	Evergreen Forest	Hay/Pasture
Developed	Mixed Forest	Cropland
Barren	Shrubland	Herbaceous Wetland
Deciduous Forest	Grassland	Woody Wetland



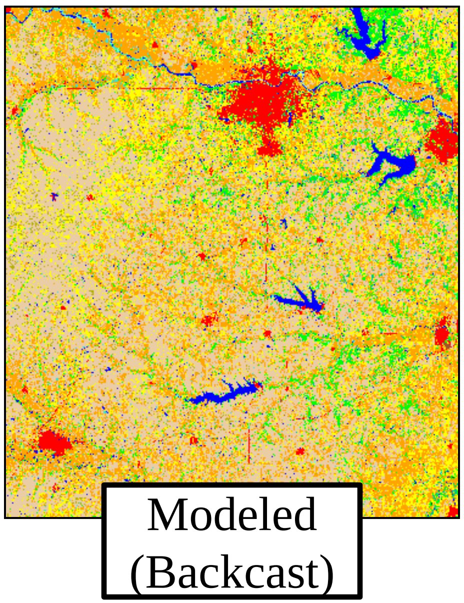
Historical – Projected Land-cover Database – 1938 to 2100



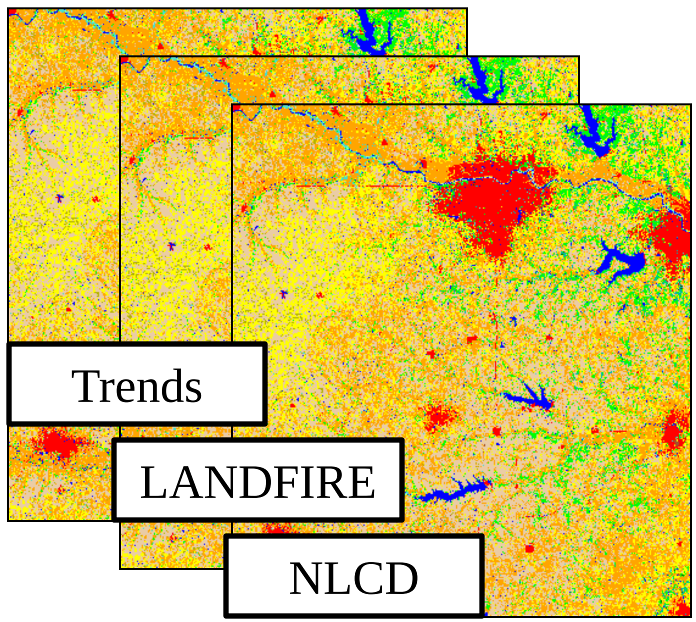
USGS Role - Consistent Land-cover Databases: Historical, Current, and Projected Land-cover

Consistent USGS Land-cover Database

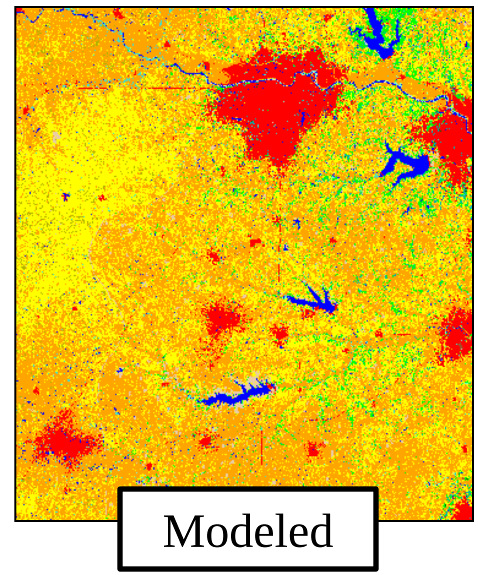
Historical



Contemporary (Satellite Era)

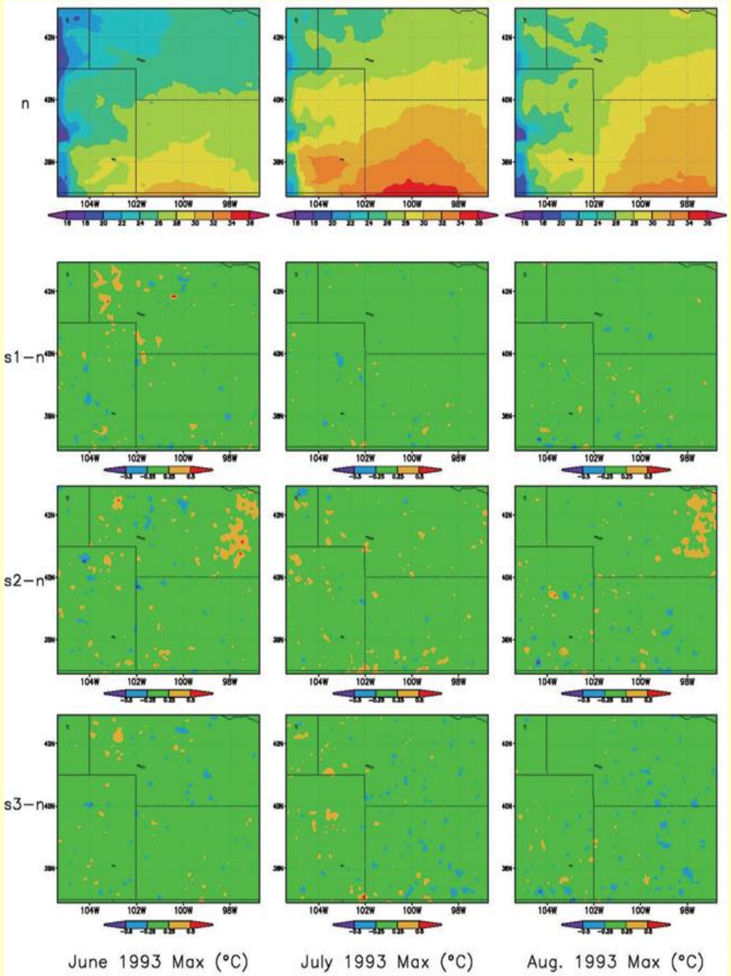


Future Scenarios



RAMS/LEAF2/GEMTM Climate Modeling

Averaged maximum monthly air temperature shown



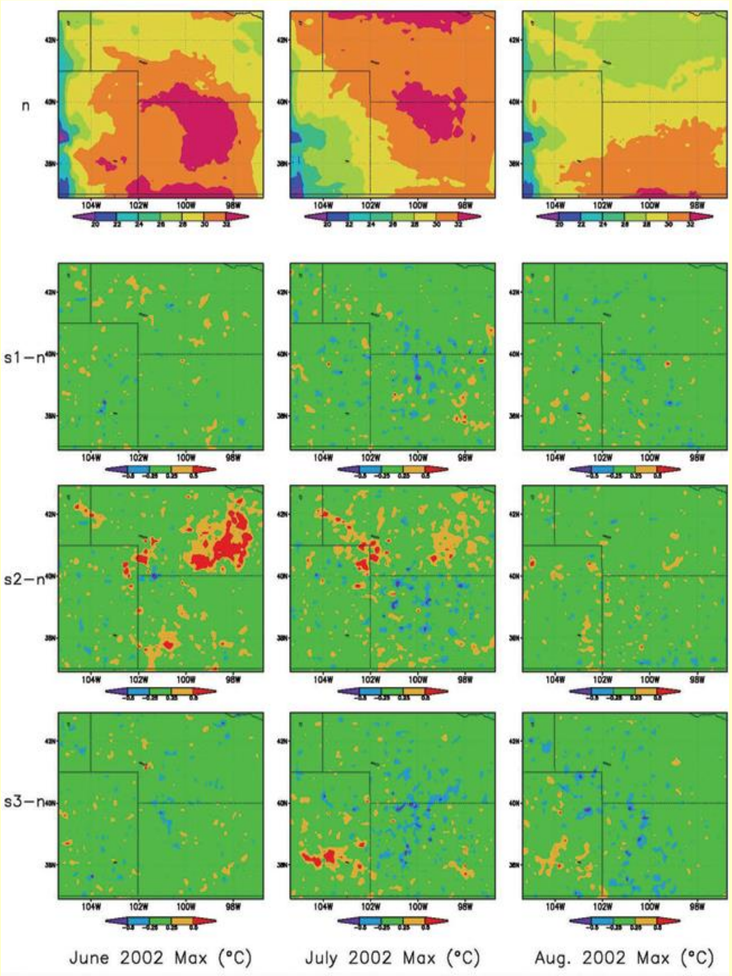
“Wet” year (1993)

1992 NLCD baseline run

Trends extrapolation scenario

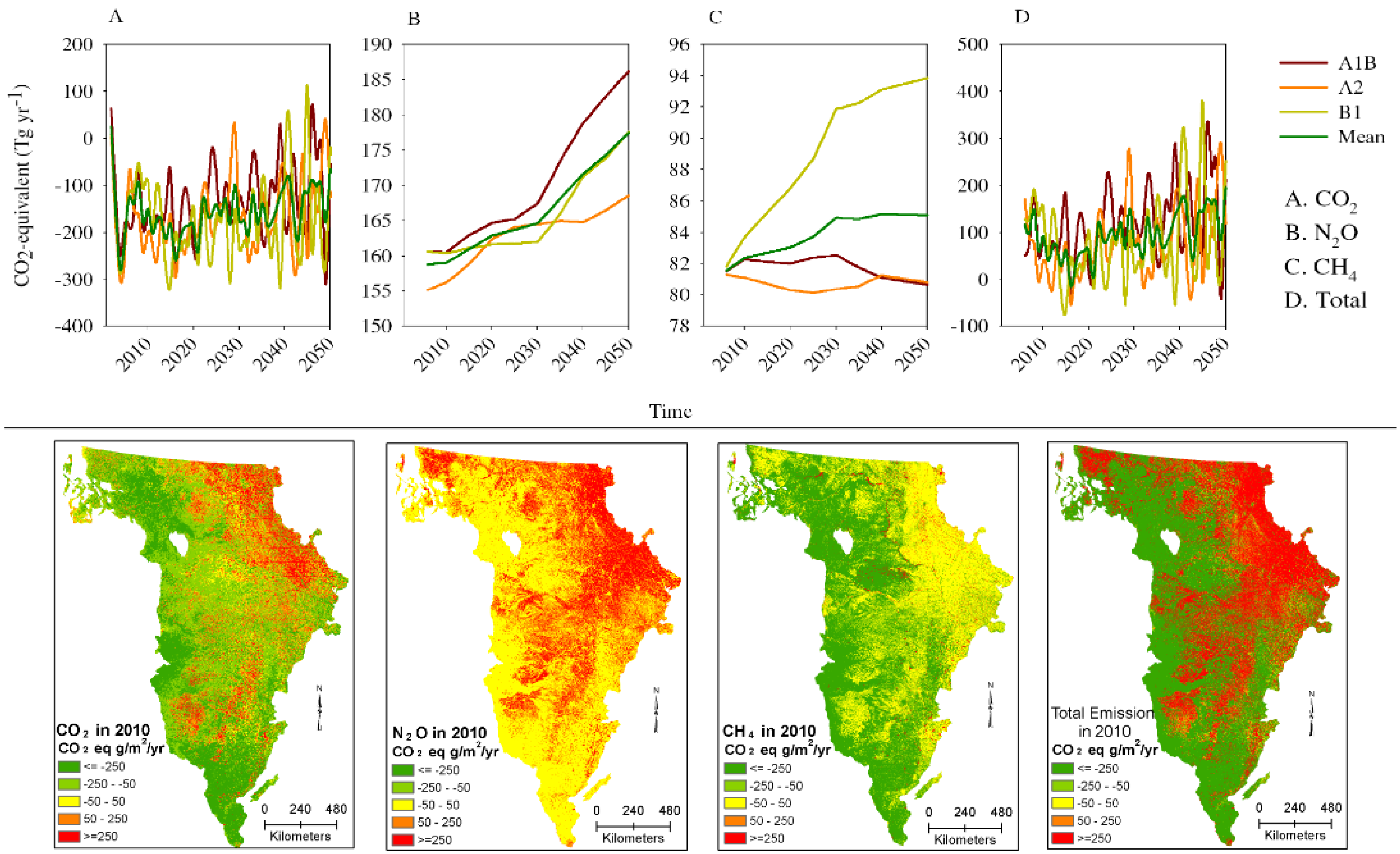
Agricultural decline scenario

Agricultural expansion scenario



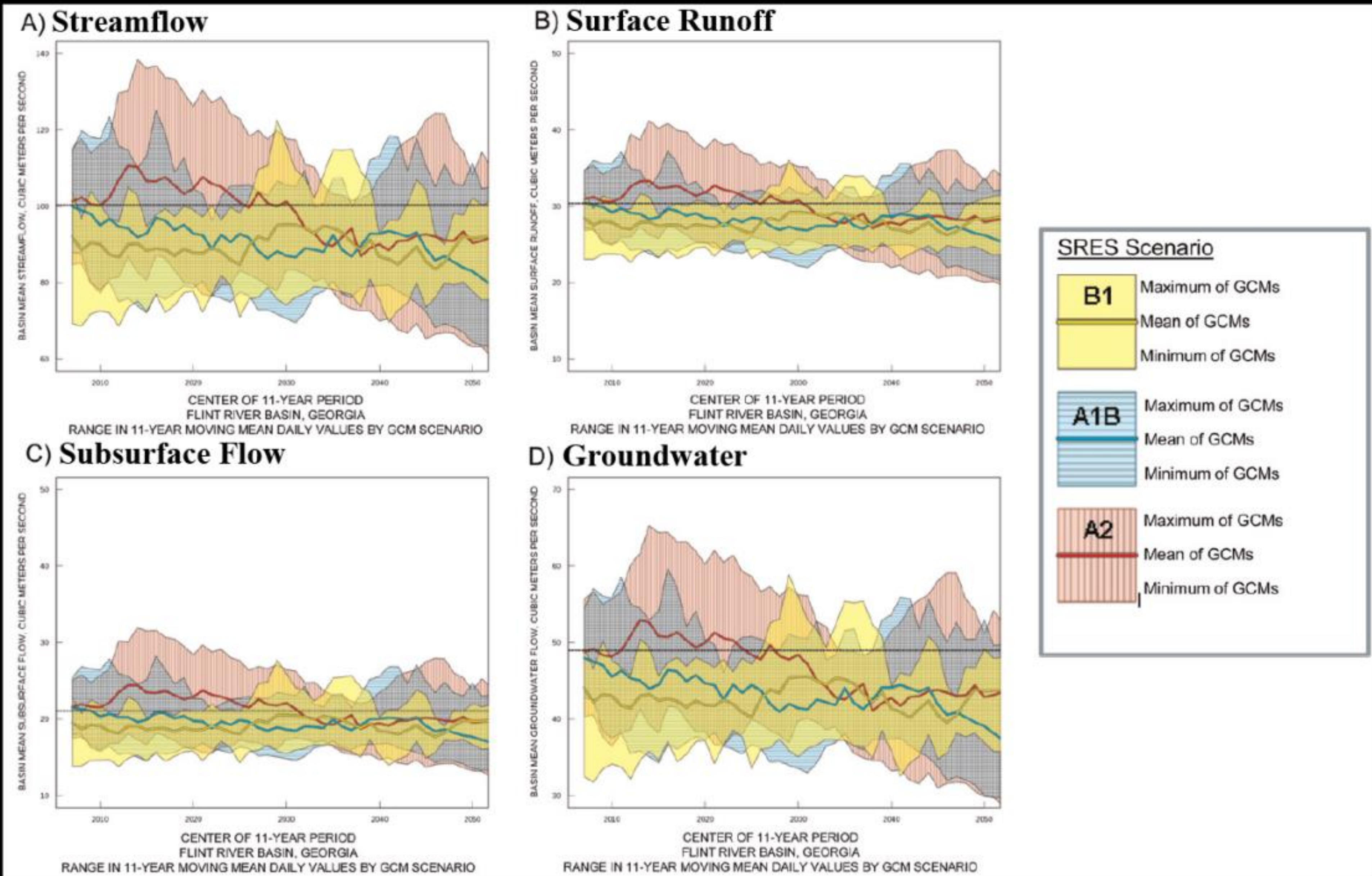
“Dry” year (2002)

Global Warming Potential of GHGs



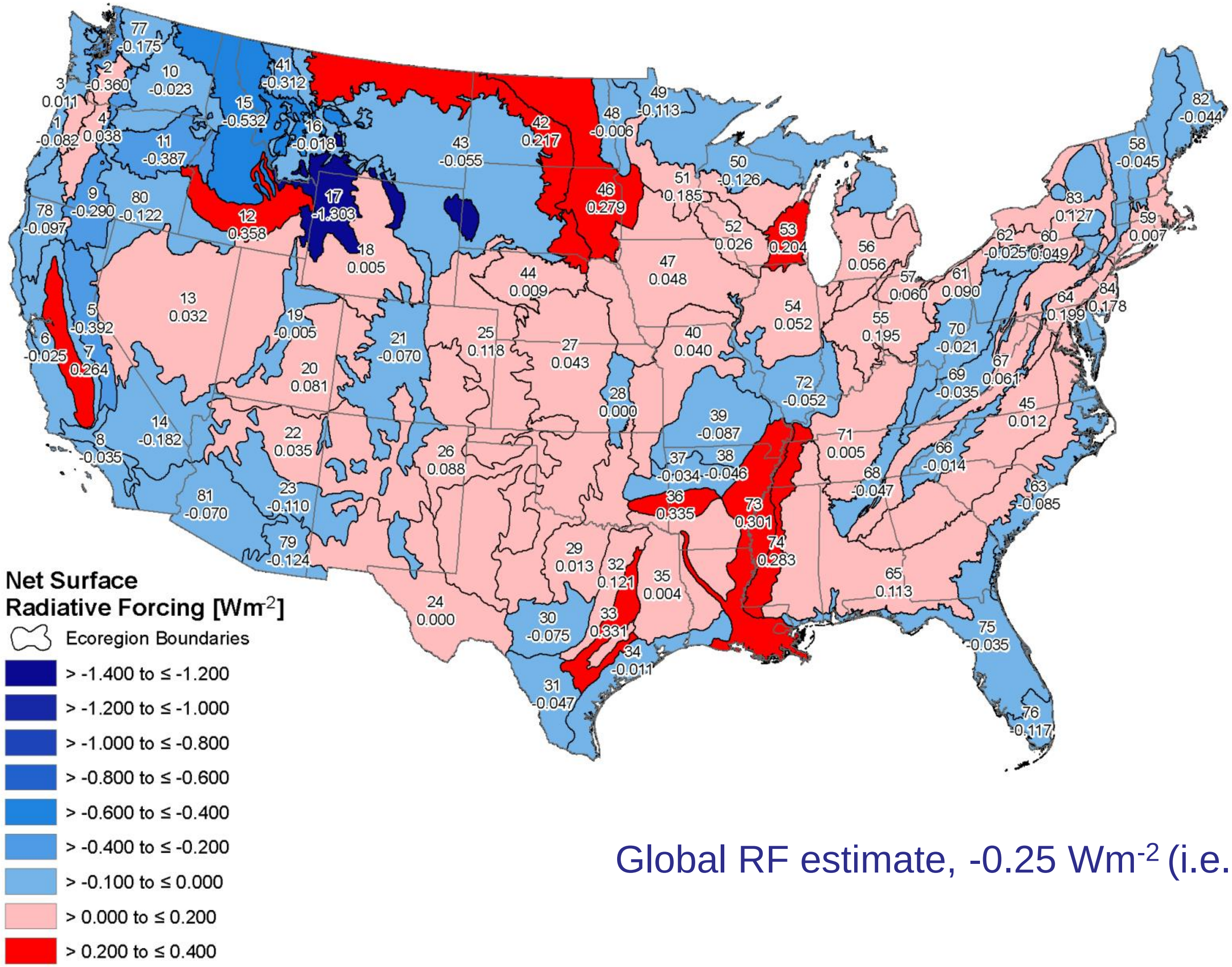
USGS

Hydrologic Impacts of Projected LULC Change



Impacts of LULC Change on Radiative Forcing

- **Found a large *<u>regional</u>* variation in radiative forcing due to LCLU albedo change, varying from -1.303 Wm^{-2} (Middle Rockies) to 0.358 Wm^{-2} (Snake River Basin)**



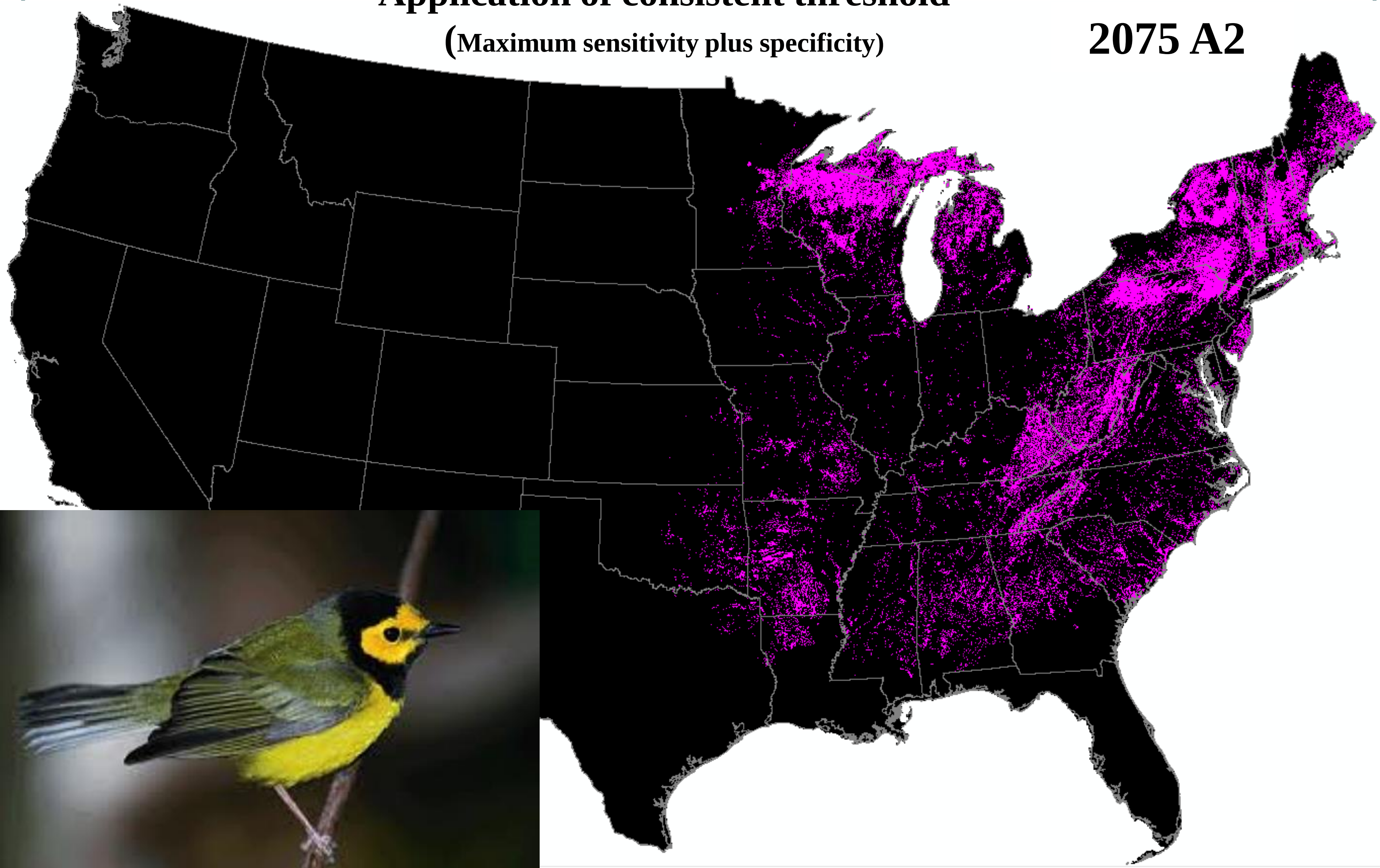
Global RF estimate, -0.25 Wm^{-2} (i.e., cooling)

Hooded Warbler – 2001 to 2075 Range (3 Scenarios)

Application of consistent threshold

(Maximum sensitivity plus specificity)

2075 A2



Two-pronged approach to LULC Modeling

- **USGS EROS strength has been regional- to national-scale land cover mapping (NLCD, Landfire, etc.)**
- **LULC scenarios and spatial projections produced for Landcarbon are consistent with this scale of focus**
- **Focus #1 – Continued development of periodic LULC projections based on latest suite of global climate scenarios**
  - "Standardized" LULC projections, consistent with downscaled assumptions from accepted global climate scenarios, facilitate ecological assessments that can be compared across scales and different geographic regions.
  - A valuable product, however it's obvious there is no "one-size-fits-all" in the scenario/LULC modeling stakeholder group.

Two-pronged approach to LULC Modeling

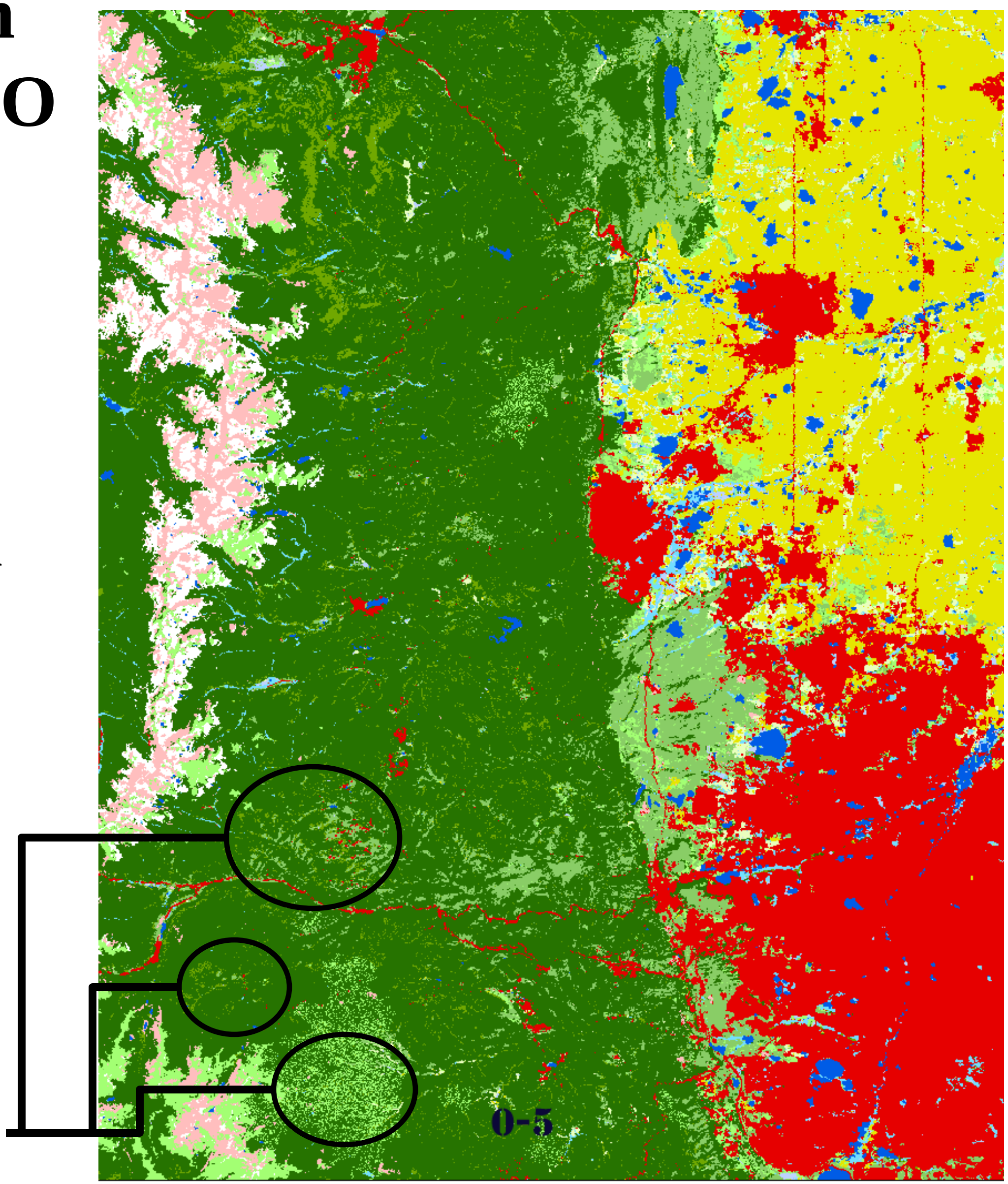
- **Focus #2 – Development of flexible, powerful, yet user-friendly LULC modeling tool that enables stakeholders to develop their own, custom LULC projections to suit their unique application**
- **Framework Components**
  - **<u>Stakeholder workshops</u>** – gather aggregate stakeholder needs for such a framework
  - **<u>LULC model</u>** – Model capable of modeling multiple resolution (spatial, thematic, and temporal), as well as the complete suite of potential landscape changes
    - Not only anthropogenic (land-use) change, but also natural vegetation succession, fire, and climate-induced vegetation shifts.
    - Multi-tier modeling framework being built, with land-use modeling, fire, and natural vegetation models running simultaneously
  - **<u>Web-based Resources</u>**
    - Data – LULC data, supporting independent variables, ownership, climate, etc.
    - Other Resources – Model documentation, user discussion, user-created resources (probability surfaces, other data layers, etc.)

CHANGE Simulations of Broad LULC Classes in the Vicinity of Denver, CO

Projections from 2010 (Simulation Year 0) through 2045 (Simulation Year 45)

Captures both anthropogenic (land use – *FORE-SCE*) and natural change (fire, veg succession, etc. - *LADS*)

- **Red – Developed**
- **Yellow – Agriculture**
- **Green – Natural Vegetation**
- **White/Pink – Snow and Rock**
- **Blue – Water and Wetlands**



Fire and corresponding vegetation succession

http://landcover-modeling.cr.usgs.gov